

Comparison of mortality of *Quercus stellata* (post oak) after a Central Texas drought

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ABSTRACT

A one-year drought in central Texas changed the structure of a *Quercus stellata* community. The density of live *Q. stellata* trees decreased by 22% and the density of standing dead increased by 7.9 times from eight dead to 63 trees/ha dead in 2012 after the drought. The total live plus standing dead trees did not change. Before the drought, dead trees were in the 22-31 cm diameter size class and after the drought in 2012, they were mostly between the 15 and 29 cm diameter size classes. No live or dead trees were found < 9 cm in diameter before the drought and no live trees and only two standing dead tree <18 cm in diameter were found after the drought. Understory woody vines, shrubs and juvenile trees decreased by 70% after the drought. *Quercus stellata* juveniles decreased by 84% to a density of 300 plants/ ha after the drought. Woodland or savanna communities can change rapidly after shifts in environmental conditions, but direction of the changes are difficult to predict. Published on-line www.phytologia.org *Phytologia* 100(3): 1-5 (Sep 21,, 2018). ISSN 030319430.

KEY WORDS: community structure, density, basal area, drought effects, standing dead

Aridity and drought are not the same. Aridity is related to climate and describes long term dry conditions while drought is relatively short term and concerns a temporary state of dryness of the weather (Mishra and Singh 2010; Djebou and Clement 2017). Deserts are dry, but the climate is described as arid while other biomes have more rainfall than deserts but have periods of dryness or droughts. The consequences of aridity and drought on plant communities varies due to the physiological and morphological characteristics of the plants tolerance to dry conditions.

The central Texas Edwards Plateau Region extends about 440 km east to west from the San Antonio-Austin area, with an east to west rainfall gradient with a mean of 84 cm/yr in the east and 38 cm/yr in the west. Rainfall is not equally dispersed and there are usually peaks in May and September with very little in June, July and August (National Climatic Data Center 2012). The annual rainfall can be misleading, because means have varied from 13 to 132 cm/yr (5 to 52 inches/yr) in the east with successive years of below or above average rainfall.

Plant communities, including woodland or savanna communities, can change rapidly especially after stressful or unusual conditions including droughts (Allen and Breshears 1998; Breshears et al. 2005; Kane et al. 2011).The Edwards Plateau Region in the past was more grassland and savanna, but is now known for its high density and basal area of *Juniperus ashei* (mountain cedar, cedar or ashe juniper) and *Quercus fusiformis* (Escarpment or Hill Country live oak) (Van Auken 1988). In addition to *Q. fusiformis*, other fairly numerous oak species found in various places in the region are *Q. buckleyi* (Texas oak), *Q. laceyi* (Lacey oak), *Q. marilandica* (blackjack oak), *Q. shumardii* (Shumard oak), *Q. muehlenbergii* (chinkapin oak) and *Q. stellata* (post oak)(Texas Forest Service 2018).

We have been observing a *Q. stellata* population in the Edwards Plateau for over seven years (Bush and Van Auken 2015), and as with many *Quercus* species in North America, this central Texas community seems to be changing. Changes appear to be widespread across North America and involve many *Quercus* species (Lorimer 1992; Lorimer et al 1994). There is evidence for a lack of recruitment of mature *Quercus* trees (Shumway et al. 2001; Ryniker et al. 2006; Cowell and Hays 2007). This recruitment failure could be caused by erratic seed production, fruit consumption, browsing damage, decreased fire frequency, low-light conditions under the canopy, and/or climatic variability (Abrams 2003). These features do not seem limiting, but there is still reduced recruitment into the adult populations (Lorimer 1992; Lorimer et al 1994). However, drought effects have not been examined.

Few *Quercus stellata* communities have been reported in the eastern part of the central Texas Edwards Plateau region (Correll and Johnston 1979; USDA 2018). Texas drought history had been reconstructed for the past 300 years by aging and comparing *Q. stellata* growth rings (Stahle and Cleaveland 1988), but community structure has not been examined until recently. We previously compared a managed and a non-managed *Q. stellata* community and found major ecological differences (Bush and Van Auken 2015). One community did not have any *Juniperus ashei* trees because of management (removal) and a higher *Q. stellata* density but lower total community density. The non-managed community had a total community density ten times higher than the managed community because of the presence of *J. ashei* trees. Basal area of *Q. stellata* was not significantly different, but total community basal area increased 41% because of the presence of *J. ashei*. Understory juvenile woody species density was also different, with total density 5.3 times higher in the managed community mostly because of the density of seedlings of juvenile *Ulmus crassifolia* plants (fall elm or cedar elm). In addition, *Q. stellata* juvenile density was fifteen times lower in the unmanaged community.

In October of 2010, a 12 month drought began (National Climatic Data Center 2012). The October rainfall for Boerne, Texas (adjacent to the study site) was 14% of the monthly average from 1946-2011. From October 2010 through September 2011 monthly rainfall for Boerne, Texas was well below the average (from 1946-2011). A general survey of Texas estimated between 100 and 500 million trees were killed by the 2010-2011 drought (2 to 10% of probably 4.9 billion trees in Texas, Edgar 2012). Anecdotal observations suggested increased mortality among established *Q. stellata* in the community on the Cibolo Preserve in Boerne, Texas occurred during this time, but was not quantified.

PURPOSE

The purpose of this study was to compare one *Q. stellata* community at two time periods. The time periods were pre- and post-drought. Phytosociological data from the *Q. stellata* community collected prior to the drought that started in 2010 will be compared to phytosociological data collected from the same place in the *Q. stellata* community but collected in May of 2012 after the one-year drought.

SPECIES

Quercus stellata Wangenh. (post oak), the species studied, is a moderate-sized deciduous tree found from central Texas to the Atlantic Ocean in the east, north to Massachusetts and in the central U.S. north to Kansas (Correll and Johnston 1979; USDA 2018). In Texas, it is found in east Texas westward into the eastern part of the central Texas Edwards Plateau. It may form relatively open, upland savanna or woodland, usually on sandy soils. It has been studied in the more eastern and northern parts of its range (Sims 1988), but the few central Texas *Q. stellata* populations are mostly unstudied. It is reported in the Cross-timbers region of north Texas along with other *Quercus* species in scattered populations. Mixed with these *Quercus* populations is *J. ashei* that is present throughout most of central Texas (Van Auken 2016). In the northeastern area called the Lampasas Cut-Plain, it is found in woodland and forested areas with other *Quercus* species (Gehlbach and Amos 1988).

METHODS

Characteristics of the woody vegetation in the 20 ha woodland portion of a managed 30 ha *Q. stellata* savanna were examined. The community was on the 250 ha Cibolo Preserve in Kendall County, central Texas (29.7691°N and 98.6935°W). The initial phytosociological study (Bush and Van Auken 2015) was carried out in May of 2010 using the quadrat procedure (Van Auken et al. 2005). Twenty-five square meter quadrats (5 m x 5 m) were established along a belt transect line within the *Q. stellata* woodland. Two-hundred four quadrats were used to sample trees in 2010 and 120 quadrats were used in 2012. The diameter of each adult tree, live or dead (3 cm in circumference at 1.57 m), was measured with a tree caliper and recorded in each 25 m² quadrat. Density and basal area were calculated in order to describe the plant community. In the understory, juveniles (< 0.5 m in height or >0.5 m in height but < 3 cm in circumference) were counted in 1020, 1 m² quadrats in 2010 and in 2012, juvenile plants in 600, 1 m² quadrats were counted and density was calculated. For overstory trees, density stabilization curves indicated sample adequacy for both sampling times (see Van Auken et al. 2005). From the tree data, diameter size class histograms were constructed and total number as well as live and dead trees in each size class is presented (Ryniker et al. 2006).

RESULTS

There were only three tree sized species found in the overstory of the community studied and only *Q. stellata* density and basal area were examined and presented in the present study (Table 1). The number of live, dead and total *Q. stellata* stems found were counted and the density and basal area were calculated (Table 1). There were only four dead trees found and measured the first year of the study, but 19 dead trees were found and measured after the drought in 2012 (presented as density/ha). Total density of *Q. stellata* trees (live and standing dead) was inspected before and after the drought. Density was 218 and 227 trees/ha respectively but only a slight increase in density (+4% difference in 2012, Table 1). However, the density of live trees in 2012 decreased 22% and the density of standing dead trees increased 7.9 times to 63 stems/ha (Table 1). There was a 3% decrease in total *Q. stellata* basal area (live and dead) in 2012 (Table 1). The live *Q. stellata* basal area decreased by 25%, but the *Q. stellata* standing dead basal area increased 6.7 times (Table 1).

Prior to the drought, the four dead trees were in three of the mid-sized classes examined (Figure 1). After the drought, size class distributions indicated that the small to average sized *Q. stellata* trees size classes (15-33 cm diameter) had most of the mortalities (Figure 2). The largest tree found in the community after the drought was present prior to the drought (Figures 1). Other live, large *Q. stellata* trees were found before the drought, but not after the drought probably because of a smaller number of quadrats sampled after the drought. All of the smallest trees examined after the drought were dead (Figure 2). There were a few trees that died in the larger size classes, but only 8% of the total.

The understory density of woody species also changed after the drought (Table 2). There were 11 woody species including woody vines, shrubs or juvenile trees found in the understory prior to the drought in 2010 and 10 species of woody plants found in the understory of the community after the drought in 2012 (Table 2). There was an overall 70% decrease in density of the understory woody species from 65,549 plants/ha to 19,050 plants/ha with most species declining after the drought (Table 2). *Ulmus crassifolia* (cedar elm) juveniles were the most common woody species both before and after the drought. Juveniles of *Q. stellata*, the dominant overstory species decreased by 84 % to 300 plants/ha after the drought.

DISCUSSION

It has been suggested that the 2010-2011 drought caused the death of 2 to 10% of the estimated 4.9 billion trees in Texas. This information is hard to confirm especially for *Q. stellata* communities. In

the present study, we took advantage of a previous, recent survey (pre-drought) to estimate the actual effects of the drought on a *Q. stellata* community by re-sampling the population immediately after the drought. We report a decrease of 22% of live trees in a *Q. stellata* community in central Texas, or a loss of approximately 1,260 *Q. stellata* trees in the 20 ha woodland part of the 30 ha savanna. We were able to confirm anecdotal observations that suggested increased mortality among established *Q. stellata* in the community on the Cibolo Preserve in Boerne, Texas. Other droughts have occurred here in the past including a major drought in the mid-1950s, but historical data of *Q. stellata* mortality or juvenile recruitment after this drought was not reported (Stahle and Cleaveland 1988).

Drought or short term lack of water is a major limiting factor for plant growth and production. Many *Quercus* species have well documented morphological, biochemical, and physiological adaptations to drought (see Abrams 1990). Morphologically, many species of *Quercus* have leaf curling (Abrams 1990), and at least one species of *Quercus*, *Q. douglasii*, shows leaf abscission during drought (Griffin 1973).

Physiologically, plants may show decreases in photosynthetic rate and growth, a reduction in stomatal conductance, cell dehydration, and an increase in chlorophyll degradation in response to drought. However, many *Quercus* species have more favorable responses to drought than co-occurring species. Under drought conditions several *Quercus* species have higher photosynthetic rates, smaller decreases in photosynthetic rates with drought, higher water use efficiency, and later stomatal closure than co-occurring species (Hinckley et al. 1979; Reich and Hinckley 1980; Bahari et al. 1985; Abrams 1990; Reich et al. 1990; Manes et al. 2006; Cotrozzi et al. 2017; Jafarnia et al. 2018). Many of these responses are also more favorable during drought for those species of *Quercus* that occur in drier areas when compared to their more mesic counterparts; and similarly, individuals for a given species from drier areas have more favorable responses than individual from the same species in wetter areas (Cotrozzi et al. 2017; Jafarnia et al. 2018). Although drought tolerance of many *Quercus* sps. are well documented (see Abrams 1990), it is also well-known that drought can influence the structure and replacement dynamics of many *Quercus* plant communities globally.

Increased tree mortality due to drought and heat has been shown in a number of studies where a *Quercus* sp. was the dominant or co-dominant (Allen et al. 2010). A dieback in *Q. robur* in Italy resulted from a shift from wetter to warm and dry summers (Colangelo et al. 2018). Similar information for other species of *Quercus* has been reported in Turkey, France, Poland, and Spain (see Allen et al. 2010). In North American, *Quercus* dieback due to drought has been shown for the upland temperate mixed forest in the southeast, northeast, and mid-west (Kessler Jr 1989; Starkey and Oak 1989; Starkey et al. 1989; Stringer et al. 1989; Tainter et al. 1990; Clinton et al. 1993; Jenkins and Pallardy 1995; Lawrence et al. 2002; Oak et al. 2004; Starkey et al. 2004; Heitzman et al. 2007), and in a savanna in Minnesota (Faber-Langendoen and Tester 1993). While our study adds to these documented dieback events for *Quercus* species, it is not known what the impact of this dieback will have on the long-term *Q. stellata* community structure.

Some studies have documented long-term changes in *Quercus* community structure. The drought tolerant *Q. pyrenica* displaced *Pinus sylvestris* as a result of droughts and shifts in climate (Fernández-de-Uña et al. 2018). As with most mortality events, drought is not the only factor to consider when determining long-term effects of tree mortality. We previously examined the replacement dynamics of *Q. stellata* in this same community and found little potential for replacement of mature trees as indicated by the lack of juveniles (Bush and Van Auken 2015). This phenomenon has been described for other *Quercus* species across North American forests since the end of the last glacial (Delcourt et al. 1983; Delcourt and Delcourt 1985; Betancourt et al. 1990; Russell and Fowler 2002; Abrams 2003; Aldrich et al. 2005; Ryniker et al. 2006; Cowell and Hayes 2007; MacDougall 2008). Various reasons have been cited for recruitment failure (see Ryniker et al. 2006) including abiotic or biotic factors such as light levels, and

competition or herbivory by various animal populations (Lorimer et al. 1994; Nathan and Muller-Landau 2000; Collins 2003; Haas and Heske 2005; Van Auken 2009; Van Auken and Bush 2009). It has been well documented that as water becomes more limiting, plant competition will increase (see Fowler 1986).

One of the greatest challenges for plant ecologist is to understand how tree mortality will affect the composition of most forests under climate change scenarios (Anderegg et al. 2012). While we have documented the increased mortality of *Q. stellata* as a result of drought in this community, it is not known if drought or other factors such as competition, disease, and herbivory are compensatory or additive.

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Table 1. Density and basal area before and after a drought for all *Quercus stellata* trees (live, dead, and total) in woodland at the Cibolo Preserve, Kendall County, Texas are presented. Change values are differences between 2010 and 2012 are percent values or times larger or smaller than the 2010 value. Data was collected in May of 2010 and 2012, before and after one-year drought.

	Status	Density (trees/ha)	Basal Area (m ² /ha)
2010	Live	210	16.7
	Dead	8	0.6
	Total	218	17.2
2012	Live	163	12.6
	Dead	63	4.0
	Total	227	16.7
Change	Live	-47 (-22%)	-4.1 (-25%)
	Dead	55 (7.9 x)	3.4 (6.7 x)
	Total	9 (4%)	0.5 (-3%)

Table 2. Phytosociological data of woody juveniles (< 0.5 m in height) for the *Quercus stellata* woodland part of a savanna located at the Cibolo Preserve, Kendall County, Texas is presented. One thousand and twenty 1 m² were examined in 2010 and 600, 1 m² quadrats were examined in 2012. Data was collected in May of 2010 and 2012, prior to and following a one-year drought.

Species	2010	2012	% or X Change
	Density	Density	
<i>Ulmus crassifolia</i>	21000	11017	-48
<i>Smilax bona-nox</i>	6389	4317	-27
<i>Celitis laevigata</i>	2389	1867	-68
<i>Quercus stellata</i>	1833	300	-84
<i>Juniperus ashei</i>	222	50	-77
<i>Diospyros texana</i>	194	267	+38
<i>Ilex deciduas</i>	111	0	-100
<i>Sideroxylon lanuginosum</i>	56	50	-11
<i>Berberis trifoliata</i>	56	0	-100
<i>Parthenocissus quinquefolia</i>	28	183	+6.5x
<i>Quercus laceyi</i>	633	0	-100
<i>Cretaegus sp.</i>	0	267	+100
<i>Prosopis glandulosa</i>	0	100	+100
Total	64549	19050	-70

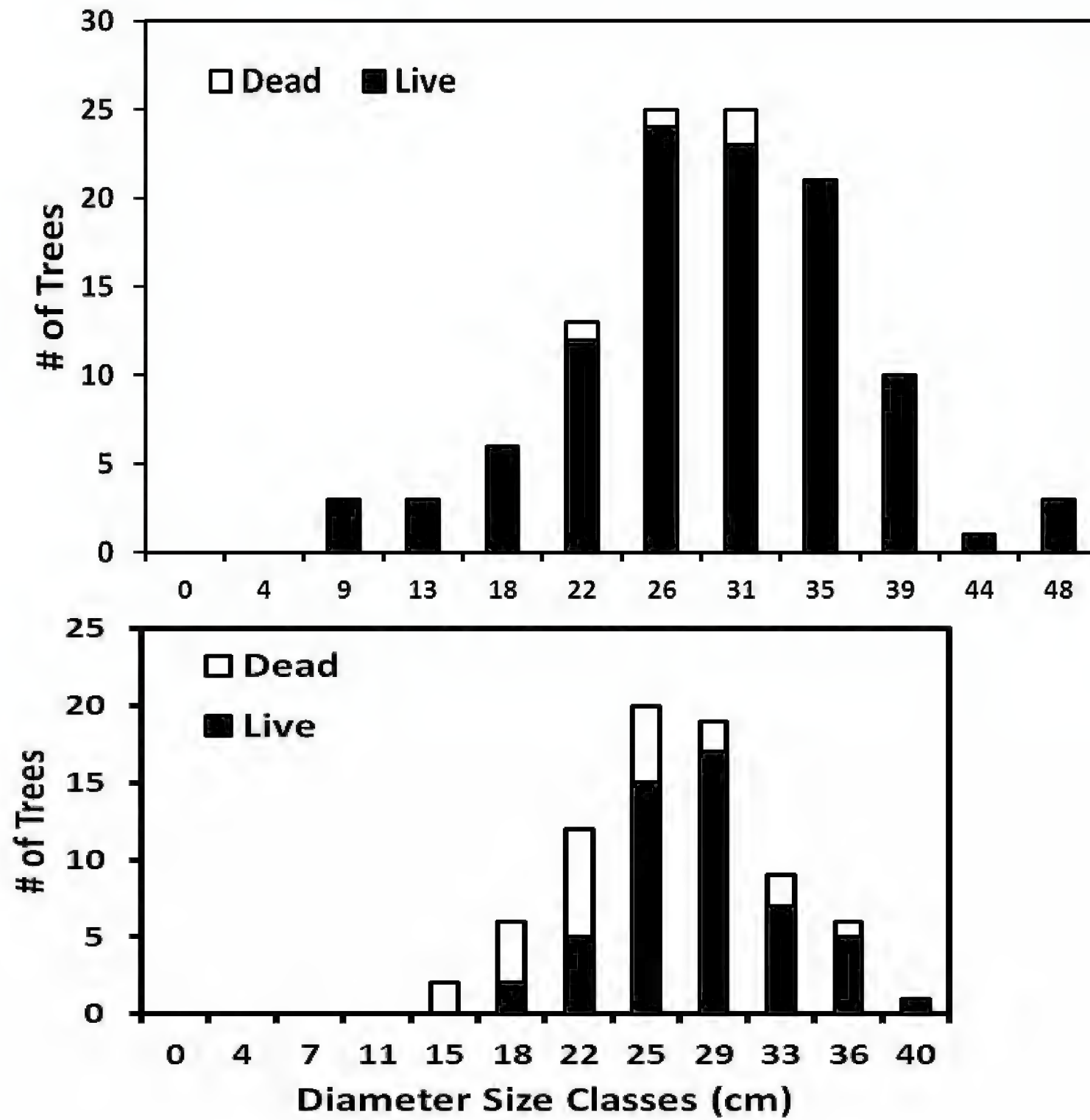


Figure 1 (upper). Diameter size class histogram for a *Quercus stellata* community at Cibolo Preserve, Kendall County, Texas for data collected in May 2010 before a one-year drought.

Figure 2 (lower). Diameter size class histogram for a *Quercus stellata* community at Cibolo Preserve, Kendall County, Texas for data collected in May 2012 after a one-year drought. Notice the lack of small diameter and very large diameter trees in the May 2012 graph(lower) vs. the 2010 (before drought, upper).